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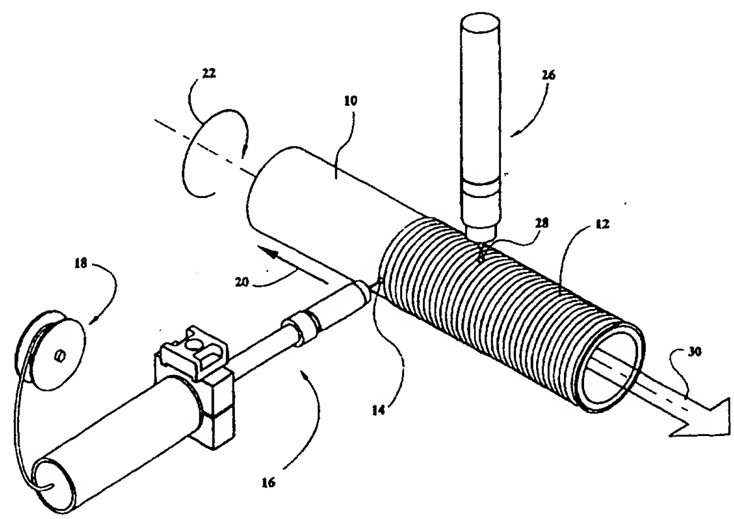
(54) Title: DUAL PASS WELD OVERLAY METHOD AND APPARATUS



(57) Abstract

A bead (12) of overlay material is applied onto a tube (10) by melting the overlay material. When a portion of the bead (12) has solidified, that portion is reheated using a second welding process. The tube (10) is rotated with respect to the weld heads (16, 26), while the weld heads (16, 26) move along the longitudinal axis of the tube (10). The first weld head (16) employs a gas-metal arc welding process, and the second weld head (26) employs a gas-tungsten arc welding process. The apparatus for the method includes a frame supporting the tube (10) for rotation about its longitudinal axis. A movable support adjustably supports the weld heads (16, 26) and moves the heads (16, 26) along the longitudinal axis of the tube. A weld overlay material feeder (18) is operatively associated with the first head (16).

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"DUAL PASS WELD OVERLAY METHOD AND APPARATUS"

Technical Field

The present invention relates to a method and apparatus for overlaying metal tubing. More specifically, the invention relates to a method and apparatus which employs two separate welding processes in a single pass to overlay conventional tube stock.

Background of the Invention

When selecting metal tubing for a particular application, the demands of the application may require physical characteristics which cannot be met by a single composition. Some alloys, for example, may provide suitable characteristics in terms of mechanical properties but lack the necessary resistance to corrosion, abrasion, or both. Other alloys may provide suitable performance in resisting corrosion and abrasion but lack the requisite structural characteristics.

In such an instance, the solution is normally found in overlaying a tubing having the requisite structural characteristics with an alloy having the desired resistance to corrosion and abrasion. Such composite tubing is typically manufactured in either of two ways: by co-extruding the two

compositions during the manufacturing process or by applying a weld overlay to a pre-existing metal tube. The present invention is concerned with the latter approach.

An optimal weld overlay has several characteristics. First, the weld penetration of the tube stock is carefully controlled to ensure the optimum fusion between the weld overlay and the tube stock. Second, the exterior surface of the weld overlay will be smooth. Third, the thickness of the weld overlay and the resulting dimensions of the overlayed tube can be closely controlled. Unfortunately, using conventional weld overlay techniques, these characteristics tend to be mutually exclusive, and the weld overlay is at best a compromise. If the voltage and current of the weld head are controlled to provide the smoothest possible exterior surface, then penetration of the tube stock tends to be excessive and uneven. Stresses resulting from bending of the tube or from thermal cycling can cause the weld overlay to separate from the underlying tube stock. On the other hand, if the voltage and current of the weld head are controlled to optimize penetration, then the exterior surface of the weld overlay tends to be rough and uneven. A rough, uneven exterior surface of a weld overlay suffers numerous disadvantages. It can make the tube more difficult to bend, which can result in an uneven distribution of stresses during bending and thermal cycling. It can also affect the thickness of the weld overlay and the resulting dimensions of the overlayed tube. When the tubes are used to fabricate a tube panel, adjacent tubes with uneven surfaces can create undesirable gaps between the tubes.

Thus, there is a need for a weld overlay process and article of manufacture which provides optimum penetration of the underlying tube stock and a smooth, even exterior surface.

There is a further need for a weld overlay process and article of manufacture which can provide optimum penetration of the underlying tube stock and a smooth, even

exterior surface and also control over the thickness of the overlay and the resulting dimensions of the overlayed tube.

There is still a further need for a weld overlay process and article of manufacture which can provide optimum penetration of the underlying tube stock and a smooth, even exterior surface and also provide uniform residual stresses within the overlayed tube.

Summary of the Invention

Stated generally, the present invention comprises a process for applying a weld overlay to a tube. Using a first welding process, a bead of overlay material is applied onto a tube by melting and transferring the overlay material. In a disclosed embodiment this heating is accomplished by a metal-inert gas welding process, more specifically a pulse spray transfer. When a portion of the bead solidifies, that portion is re-heated using a second welding process. In a disclosed embodiment this re-heating is accomplished by a tungsten-inert gas welding process. In the disclosed embodiment, the tube is rotated with respect to the weld heads, while the weld heads move along the longitudinal axis of the tube. According to the disclosed embodiment, the first weld head employs a gas-metal arc welding process, and the second weld head employs a gas-tungsten arc welding process.

In a second aspect the present invention comprises an apparatus for applying a weld overlay to a metal tube. A frame supports tube for rotation about its longitudinal axis. A movable support adjustably supports first and second weld heads and is configured to move the weld heads along the longitudinal axis of the tube. The weld heads are adjustably supported on the movable support in predetermined relation to the tube. A weld overlay material feeder is operatively associated with the first weld head and, in conjunction with the first weld head, applies a weld overlay to an exterior surface of the tube.

Thus it is an object of the present invention to provide an improved method and apparatus for applying a weld overlay onto a tube.

It is another object of the present invention to provide an improved method and apparatus for applying a weld overlay onto a tube wherein the procedure both optimizes the penetration of the tube material and provides a smooth, even exterior surface.

Still another object of the present invention is to provide an improved method and apparatus for applying a weld overlay onto a tube wherein the procedure both optimizes the penetration of the tube material and provides a smooth, even exterior surface while also providing control over the thickness of the overlay and the resulting dimensions of the overlayed tube.

It is yet another object of the present invention to provide a weld overlay process and article of manufacture which can provide optimum penetration of the underlying tube stock and a smooth, even exterior surface and also provide uniform residual stresses within the overlayed tube.

Other objects, features, and advantages of the present invention will become apparent upon reading the following specification, when taken in conjunction with the drawings and the appended claims.

Brief Description of the Drawings

FIG. 1 is a schematic diagram illustrating a method of applying a weld metal overlay onto a metal tube, according to the present invention.

FIG. 2 is a perspective view of an apparatus for performing the method of FIG. 1.

FIG. 3A is an elevation view of a tube support of the apparatus of FIG. 2 with the support shown in its normal, closed position; **FIG. 3B** is an elevation view of the tube

support of FIG. 3A showing the support in its open position for accepting a metal tube therewithin.

Detailed Description of the Disclosed Embodiment

Referring now in more detail to the drawings, in which like numerals indicate like elements throughout the several views, FIG. 1 illustrates a method of applying to a metal tube stock **10** a weld metal overlay **12**. Typical examples of suitable material for the tube stock **10** would include carbon or low alloy steel. Examples of suitable weld overlay material include alloy 309 and alloy 625. However, it will be appreciated that the method and apparatus disclosed hereinbelow are equally suitable for other tube stock materials and other weld overlay materials depending upon the characteristics desired of the finished product and subject to the limitations of compatibility to the tube stock material and the weld overlay material.

The weld overlay is applied at a first location **14** by a gas metal arc welding ("GMAW") torch or weld head, also known as a metal inert gas ("MIG") torch. A wire feeder **18** is associated with the MIG torch **16** to feed a metal overlay material to the weld location **14**. In the disclosed embodiment, the MIG torch **16** is of conventional design and is the model A2521-3072T4 manufactured by Bernard. The associated wire feed **18** is also of conventional design and, in the disclosed embodiment, is the model 554D, manufactured by Miller.

The MIG torch **16** in the disclosed embodiment is longitudinally advanced past the weld head in the direction indicated by the arrow **20**, while the tube stock **10** is simultaneously rotated past the torch in the direction indicated by the arrow **22**. When viewed from the right end of the tube stock **10** as shown in FIG. 1, such that the tube stock rotates in a clockwise direction, the MIG torch **16** applies the weld overlay at a location corresponding to approximately the nine

o'clock position on the outer circumference of the tube stock. This location is advantageous because applying the weld metal overlay material to the tube stock in a vertical position minimizes dilution of the base metal and weld wire. The MIG weld head **16** oscillates in a direction parallel to the longitudinal axis of the tube stock **10** (in the same direction previously indicated by the arrow **20**) to work the weld bead further.

A gas tungsten arc welding ("GTAW") torch, also known as a tungsten inert gas ("TIG") torch or weld head **26**, is disposed to treat the weld metal overlay **12** at a point which is spaced apart from the MIG torch **16** along the longitudinal access of the tube stock **10**. In the disclosed embodiment, the TIG torch **26** is of conventional design and is the model WP17 manufactured by Weld Craft. Again as viewed from the right end of the tube stock **10** as shown in FIG. 1, with the tube stock rotating in a clockwise direction, the TIG torch **26** heats the weld metal overlay **12** at a location substantially corresponding to the twelve o'clock position on the circumference of the tube stock **10**. No wire feed is associated with the TIG torch **26**, and no additional weld metal overlay material is applied to the circumference of the tube stock **10** at the location **28** which is heated by the TIG weld head **26**.

The current and voltage of the MIG weld head **16** are controlled to optimize fusion between the weld overlay **12** and the tube stock **10**. The resulting weld overlay will tend to have a rough, uneven surface. The current and voltage of the TIG weld head **26** are then controlled to melt or to "wash" and to re-shape the outer portion of the weld bead. The re-heating process achieved by the TIG weld head **26** advantageously does not re-melt the entire weld bead. Instead, the weld bead is heated to a temperature sufficient to melt only a portion of the weld bead but not sufficient to increase dilution of the weld metal or to increase penetration into the base metal.

The use of two separate weld heads **16**, **26** with weld metal overlay material being applied only in conjunction with the first weld head **16** provides the following advantages. The voltage, amperage, and wire feed rate of the MIG weld head **16** can be controlled to optimize penetration of the weld bead without regard to the effect on the outer circumference of the bead. In contrast, the voltage and amperage of the TIG weld head can be controlled to provide fine contouring to the circumference of the weld overlay material **12**. In addition, the second heating process accomplished by the TIG weld head **26** provides for uniform residual stresses in the weld bead and lowers the hardness of the heat-affected zone by as much as 8-10 points on the Rockwell "C" scale.

To control the temperature of the tube stock and to control the rate of cooling of the weld overlay metal, water is flowed through the tube stock during the welding process, as indicated generally by the arrow **30**. The volume and flow rate of the water are sufficient to maintain this tube stock at an interior temperature of 80-100°F.

Example

309 alloy weld overlay material is applied onto carbon or low alloy steel tube stock. The current of the MIG torch **16** is set at 185-220 amps, and the voltage is set at 23-27 volts. The wire feed speed is 360-600 inches per minute, preferably 400-480 inches per minute. The tube stock is rotated at 18-40 inches per minute, preferably 20-36 inches per minute. For tube stock having a three inch diameter, the tube stock rotates from 2-4 revolutions per minute. The MIG weld head **16** applies the weld overlay material at a density of three to six beads per inch, preferably about four beads per inch. The TIG torch **26** is longitudinally spaced apart from the MIG torch by a distance of approximately five inches. The MIG process heats the weld metal to a temperature of approximately 2,400-2,500°F. By the time a particular location along the continuous weld bead has reached the TIG

torch **26**, the weld bead has solidified. The TIG torch **26** reheats the outer portion of the previously applied bead above a temperature of approximately 1,500-1,600°F to re-melt a portion of the bead. According to this method, the depth of penetration can be controlled within tolerances of approximately ±.003 inches, and the outer diameter contour and dimension can be controlled within tolerances of approximately ± .007 inches.

FIG. 2 illustrates an apparatus **100** for carrying out the method illustrated in FIG. 1. The apparatus **100** includes an elongated frame **102** having side walls **104** and **106**. One end of the tube stock **10** is gripped in a chuck **110** which is rotationally driven by an electric motor or other suitable means **111**. Rotary unions **112** cap each end of the tube stock **10**, and hoses **114** coupled to the rotary unions **112** introduce a coolant such as water into one end of the tube stock **10** and withdraw it from the other. A rotary ground **116** grounds the tube stock **10**.

The frame **102** further comprises upper rails **120** disposed along the upper edge of each of the side walls **104**, **106**. A wheeled platform **122** rolls along the rails **120**. Gears (not shown) operatively associated with the platform **122** and driven by an electric motor or other suitable means engage a gear rack **124** formed along the lower surface of each of the upper rails **120** to move the platform **122** along the length of the frame **102**.

The platform **122** includes a control panel **128** by which the voltage, current, and speed of oscillation of the two weld heads **16**, **26**, the wire feed speed of the wire feeder **18**, and the speed of movement of the platform **122** are set.

When mounted to the frame **102** as thus described, the tube stock **10** extends over the platform **122**. The MIG weld head **16**, wire feed **18**, and TIG weld head **26** are adjustably mounted to the platform **122** by a suitable

mounting means **130** so that they can be properly oriented with respect to the tube stock **10**. Affixed to the mounting means **130** is a guide **132** in the form of a short length of aluminum structural angle disposed in an inverted "V" position. The guide **132** rides on top of the tube stock **10** to maintain the proper relationship between the tube stock and the mounting means **130**. The platform **122** moves along the frame **102** to effect relative longitudinal movement between the weld heads **16, 26** and the tube stock **10**. Simultaneously the tube stock **10** rotates to effect relative rotational movement between the tube stock and the weld heads **16, 26**. The speed at which the platform **122** moves along the rails **120** of the frame **102** is controlled with respect to the speed at which the tube **10** is rotated so that the weld heads **16, 26** have advanced by a distance corresponding to the width of the weld bead **12** for each rotation of the tube.

To support the weight of the tube stock **10** along its length, a plurality of supports **140** are provided. As can be seen in FIG. 3, each support **140** includes an upright stanchion **142**. A frame **144** is mounted to the stanchion **142** for movement toward and away from the stanchion in the direction indicated by the arrow **145**. In the disclosed embodiment, movement of the frame **144** toward and away from the stanchion **142** is affected by a pair of threaded rods **146, 147**, though other suitable mechanisms may be used. The support further includes upper and lower wheels **148, 149** rotatably mounted to the stanchion **142** and upper and lower wheels **150, 151** rotatably mounted to the frame **144**.

As can be seen in FIG. 3B, the upper threaded rod **146** is disengageable from the frame **144** and pivotably opens as indicated by the arrow **154** to permit the support **140** to be positioned around the tube stock **10**. The frame **144** is then closed by turning the threaded rods **146, 147** to bring the upper and lower wheels **148-151** into contact with the outer circumference of the tube stock **10**. The spacing between the

frame **144** and the stanchion **142** is adjusted to bring all four wheels **148-151** into contact with the circumference of the tube stock. As the tube stock **10** is rotatably driven, the wheels **148-151** rotate freely to permit the tube stock to rotate within the support **140**.

At the start of the weld overlay process, the platform **122** is located at the far right end of the frame **102** as seen in FIG. 2. The three supports **140** are spaced along the length of the tube stock **10** to the left of the platform, as seen in FIG. 2, to support the weight of the tube stock.

As the platform **122** moves along the frame **102** toward the left, the rightmost support **140** is removed and repositioned to the right of the platform. As the platform **122** moves further toward the left, the next support **140** is moved out of the way and repositioned to the right of the platform. Similarly, as the platform **122** continues to move, the last support **140** is repositioned to a location on the right side of the platform as seen in FIG. 2.

There may be occasions when it would be desirable to apply a second weld metal overlay on top of the first weld metal overlay **12**. As an example, whenever a weld overlay is applied directly onto the exterior surface of a tube, some dilution of the weld metal occurs. Application of a second weld overlay provides an outer layer which is virtually pure weld metal. When applying two weld overlays, it may be desirable to use a less-expensive metal such as alloy 304 for the bottom layer and a weld metal having more of the desired chemistry and physical properties for the top layer, such as alloy 309. In such a case, the TIG weld head **26** would be moved further away from the MIG weld head **16**, and a second MIG weld head with associated wire feed would be positioned between the first MIG weld head **16** and the TIG weld head **26**. A first weld metal overlay **12** would be applied onto the tube stock **10** as previously described. At a point sufficiently spaced apart from the first MIG weld head **16** that the first

weld metal overlay **12** has solidified, a second weld metal overlay is applied by the second MIG weld head and associated wire feed. Advantageously the second MIG weld head is also positioned at approximately the 9 o'clock position with respect to the tube stock **10**. At a point sufficiently spaced apart from the second MIG weld head that the second weld metal overlay has solified, the TIG weld head **26** heats the second weld metal overlay to provide a smooth, contoured outer surface.

In the disclosed embodiment the MIG weld head **16** and the TIG weld head **26** are spaced apart by five inches along the longitudinal axis of the tube stock **10**. The longitudinal spacing of five inches between the MIG and TIG weld heads **16, 26** in the disclosed embodiment is selected because it is not physically possible to position the particular weld heads of the disclosed embodiment any closer together. However, it will be appreciated that, depending upon various factors, a portion of the weld bead **12** may have solidified before the platform **122** has moved five inches. Thus in the case of weld heads having different configurations, it is possible that the two weld heads can be positioned closer together than five inches and still achieve the desired result.

While the embodiment disclosed above employs a platform **122** which moves along the frame **102** to effect relative longitudinal movement between the weld heads **16, 26** and the tube stock **10**, it will be appreciated that relative longitudinal movement between the weld heads and the tube stock can also be achieved by holding the weld heads steady and moving the tube longitudinally with respect to the weld heads. Thus a means for effecting relative longitudinal movement between the weld heads and the tube could comprise either means for moving the weld heads while the tube remains longitudinally fixed, or means for moving the tube longitudinally with the weld heads remaining fixed.

Finally, it will be understood that the preferred embodiment has been disclosed by way of example, and that

other modifications may occur to those skilled in the art without departing from the scope and spirit of the appended claims.

CLAIMS

What is claimed is:

1. A process for applying a weld overlay to a tube, comprising the steps of:

using a first welding process, applying a bead of overlay material onto said tube by melting said overlay material;

permitting a portion of said bead to solidify; and

using a second welding process, re-heating said portion of said bead which has solidified to re-melt the outer portion of said solidified portion of said bead.

2. The process of Claim 1, wherein said process is a continuous process such that said bead of overlay material is being applied onto said tube at a first location simultaneously with a solidified portion of said bead being re-heated at a second location.

3. The process of Claim 1, wherein said first welding process comprises a gas metal arc welding process.

4. The process of Claim 1, wherein said second welding process is performed without adding any additional overlay material onto said tube.

5. The process of Claim 1, wherein said second welding process comprises a gas tungsten arc welding process.

6. The process of Claim 1, wherein said step of applying a bead of overlay material onto a tube comprises the steps of:

holding a first weld head in a substantially fixed position with respect to said tube;

rotating said tube about a longitudinal axis to bring successive portions of the outer circumference of said tube beneath said first weld head such that said bead of overlay material is applied onto said successive portions of said outer circumference of said tube; and

effecting relative longitudinal movement between said first weld head and said tube to apply said bead along the length of said tube.

7. The process of Claim 6, wherein said bead of overlay material is applied to said tube at a location on said tube which is at approximately the vertical midpoint of said tube and on a side of said tube which is rotating upward beneath said weld head.

8. The process of Claim 6, wherein said step of re-heating said portion of said bead which has solidified comprises the step of holding a second weld head in a substantially fixed position with respect to said tube such that said step of rotating said tube about said longitudinal axis of said tube brings successive portions of the outer circumference of said tube beneath said second weld head.

9. The process of Claim 1,

wherein said step of applying said bead of overlay material onto said tube comprises the step of controlling said first welding process to optimize fusion of said weld overlay to said tube without regard to the surface characteristics of the exterior surface of said weld overlay, and

wherein said step of re-heating said portion of said bead which has solidified comprises the step of controlling said second welding process to melt the outer portion of said bead without increasing dilution of the overlay material or increasing dilution of the base metal of the tube.

10. An apparatus for applying a weld overlay to a metal tube, comprising:

a frame for mounting a tube for rotation about a longitudinal axis of said tube;

a first weld head;

a second weld head;

a support mounted to said frame for adjustably supporting said first and second weld heads in such a manner as to be capable of being arranged in predetermined relation to a tube mounted to said frame, said second weld head being spaced from said first weld head along a longitudinal axis of a tube mounted to said frame;

means for effecting relative longitudinal movement between said support and said tube; and

a weld overlay material feeder operatively associated with said first weld head for supplying a weld overlay material, said weld overlay feeder being operative in conjunction with said first weld head to apply a weld overlay to an exterior surface of said tube by melting said overlay material and transfering it onto said tube;

whereby said tube is rotatable with respect to said first and second weld heads, and said first and second weld heads are longitudinally movable with respect to said tube.

11. The apparatus of Claim **10**, wherein said support is movably mounted to said frame, and wherein said means for effecting relative longitudinal movement between said support and said tube comprises means for moving said support on said frame longitudinally with respect to said tube.

12. The apparatus of Claim **10**, wherein said second weld head being spaced from said first weld head along said longitudinal axis of said tube comprises said second weld head being spaced a sufficient distance along said longitudinal axis of said tube that a portion of a weld overlay which passes beneath said second weld head has solidified.

13. The apparatus of Claim **12**, wherein said second weld head being spaced a sufficient distance along said longitudinal axis of said tube that a portion of a weld overlay which passes beneath said second weld head has solidified comprises said second weld head being spaced a sufficient distance along said longitudinal axis of said tube that a portion of a weld overlay which passes beneath said second weld head has solidified but remains heated to a temperature higher than the ambient temperature.

14 The apparatus of Claim **10**, further comprising means for oscillating said first and second weld heads with respect to said tube.

15. The apparatus of Claim **10**, wherein said first weld head is arranged with respect to said tube so as to apply a weld overlay to a location on said exterior surface of said tube which is approximately 90° offset from the top of said tube.

16. The apparatus of Claim **10**, wherein said second weld head is arranged with respect to said tube so as to heat said weld overlay at a location on said exterior surface of said tube which is at approximately the top of said tube.

17. The apparatus of Claim **10**, wherein said first weld head comprises a gas-metal arc weld head, and wherein said second weld head comprises a gas-tungsten arc weld head.

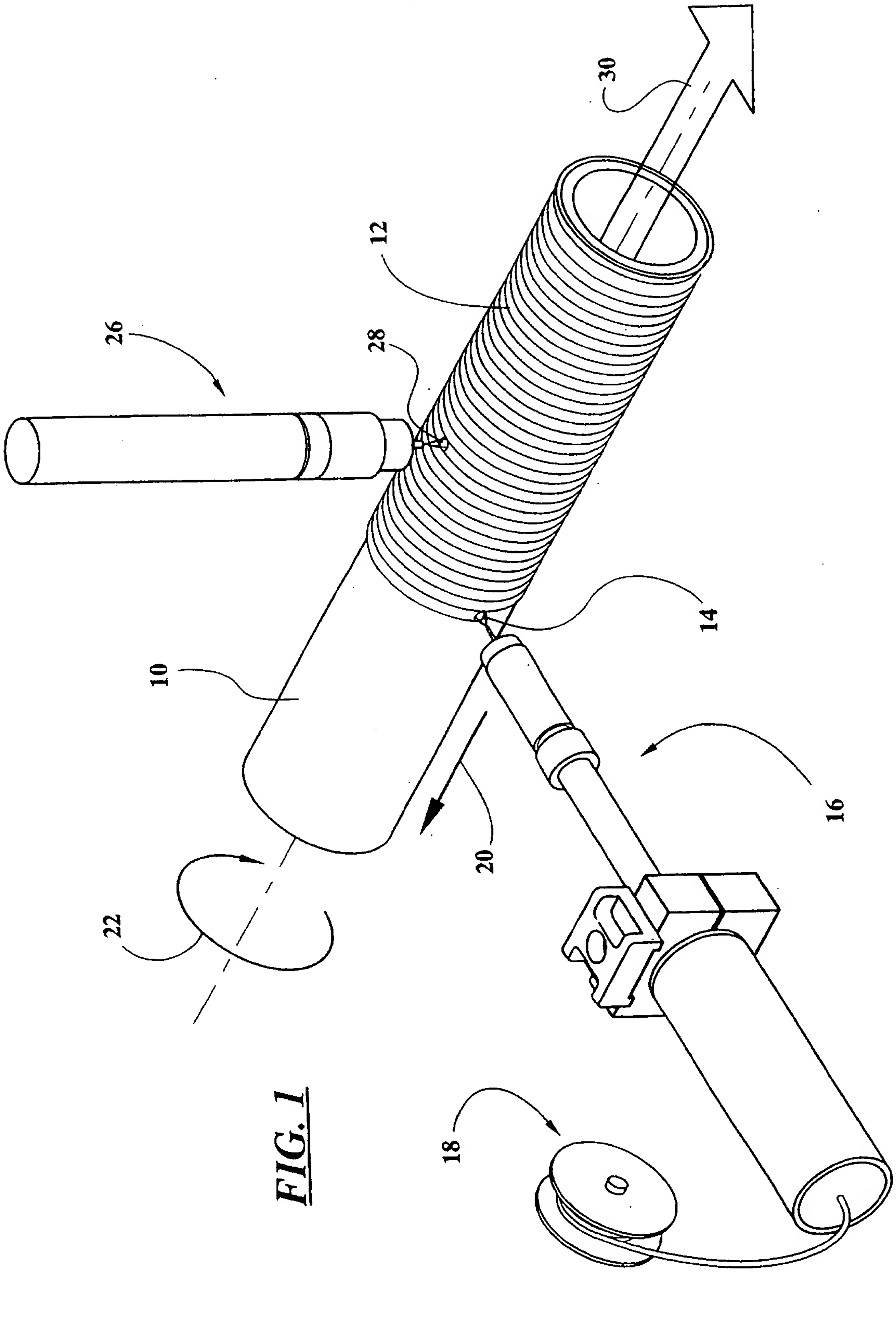

FIG. 1

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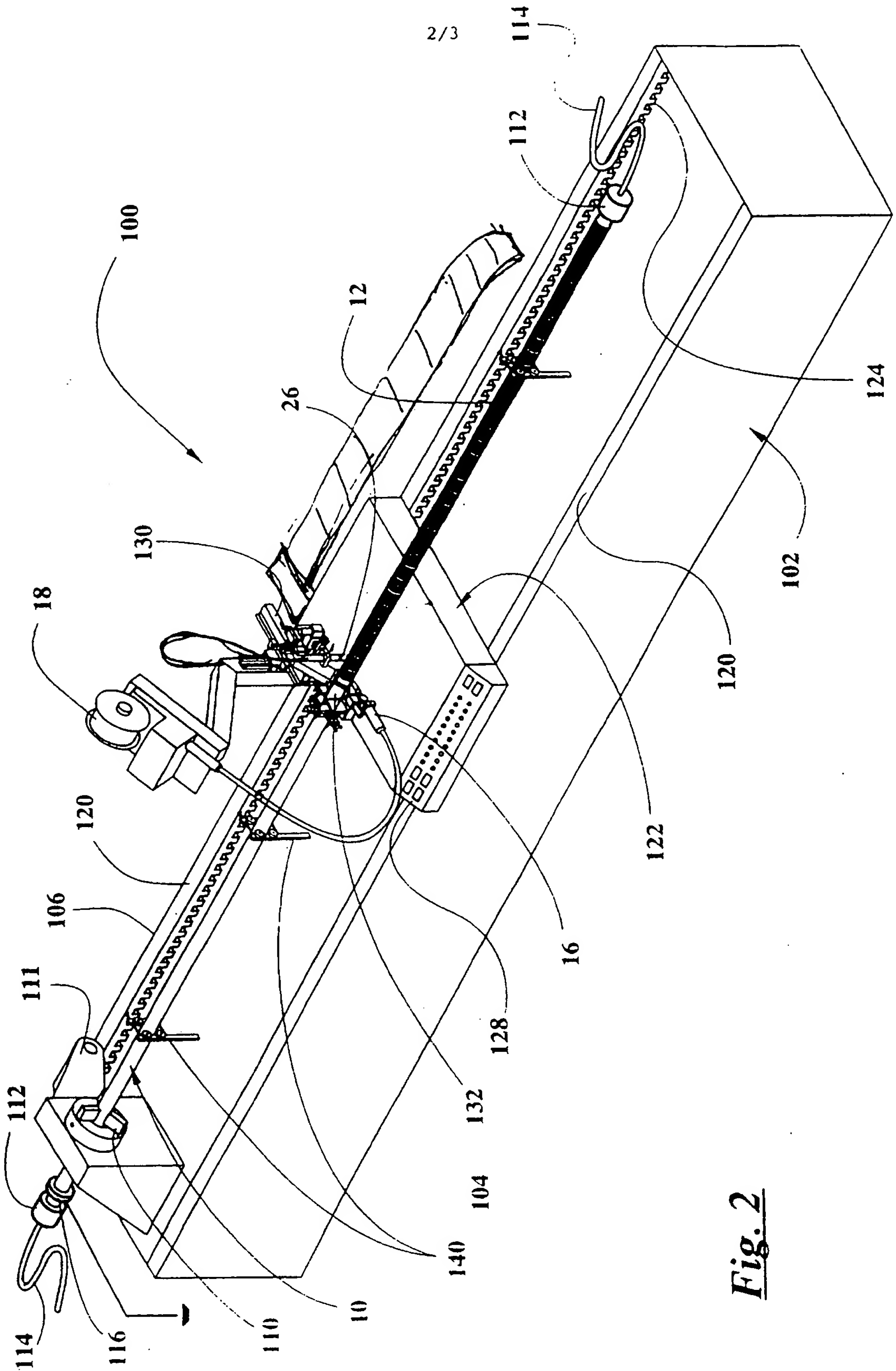
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Fig. 2

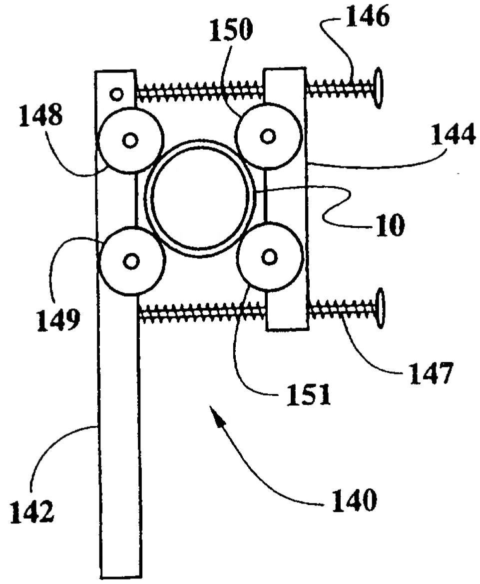
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Fig. 3A

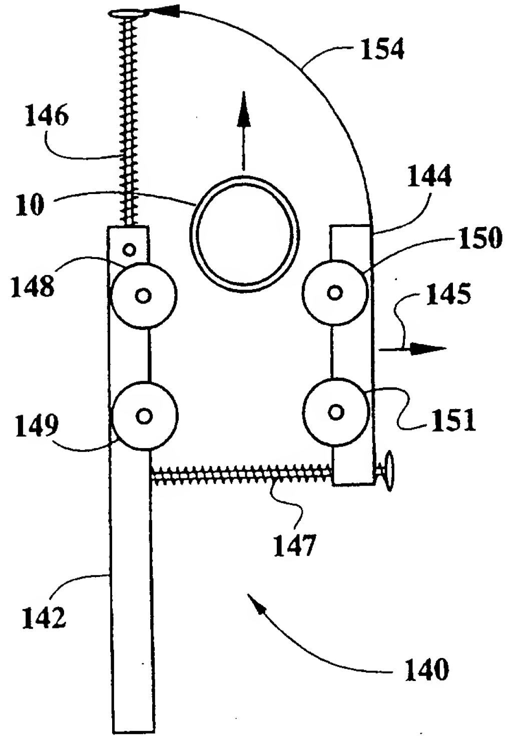
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Fig. 3B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/13661

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B23K 9/04
US CL :219/76.14, 125.11
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/61, 75, 76.12, 76.14, 76.15, 125.11, 125.12, 137R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2,813,190 A (FELMLEY, JR.) 12 November 1957 (12/11/57), see the entire document.	14
Y	US 2,756,311 A (PERSSON ET AL.) 24 July 1956 (24/07/56), see figure 1, column 1, and column 4.	1-17
Y	US 4,948,936 A (LANDRY) 14 August 1990 (14/08/90), see the entire document.	1-17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer CLIFFORD C. SHAW Telephone No. (703) 308-1712

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